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3M QUANTITATIVE PROCESS RISK SCREENING TOOL

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The 3M Quantitative Process Risk Screening Tool (QPRS Tool) has been developed as a means of assisting 3M facilities globally in evaluating and managing the risks associated with processes that use or store hazardous materials under General Duty activities. The QPRS Tool allows review of potential on-site and off-site impacts to employees, the adjacent community and the environment. The Quantitative Process Risk Screening Tool is unique to 3M, but is based on hazard evaluation techniques which have been developed and used within industry and which are supported by AIChE and industry groups. The QPRS Tool is a simple eight-step process that uses commonly available chemical hazard information primarily from Material Safety Data Sheets as well as information on the engineering and administrative safeguards provided for the process.

INTRODUCTION

There are many specific federal, state and local regulations today that address management of hazardous materials in industrial facilities. In addition, General Duty requirements have established expectations for hazard and risk management even when operations are not covered by a specific regulation.

Time and resources cannot support exhaustive analysis of each and every process, operation and activity at an industrial facility, nor do the hazards and risks presented warrant such treatment in all cases. Consequently, there is a need for a consistent approach that provides a general assessment of the risks presented by processes and other activities such that an appropriate level of process safety can be maintained. For large companies with multiple facilities it is also important that management of hazards and risks be consistent from one location to another across the organization.

The use of a semi-quantitative tool to conduct a preliminary screening of processes can be an effective method of addressing these needs. Some of the benefits of this approach include:

- Increased safety.
- Managing General Duty responsibilities.
- Fact based prioritization of issues for resource allocation .
- Maximizing benefit of investments for risk reduction.
- Improved business continuity.
- Avoiding costs associated with incidents.
- Avoiding or reducing liability.
- Internal consistency in risk reduction decisions.

SEMI-QUANTITATIVE RISK SCREENING TOOL

This Quantitative Process Risk Screening Tool (QPRS Tool) has been developed by 3M as a means of assisting facilities around the world in evaluating and managing the risks associated with processes that use or store hazardous materials. The QPRS Tool also provides an estimate of potential on-site and off-site impacts of the unintended release of hazardous materials on employees, the adjacent community and the environment.

The Quantitative Process Risk Screening Tool is unique to 3M, but is based on hazard evaluation techniques which have been developed from papers presented at CCPS conferences and used within industry and which are supported by industry groups.

The QPRS Tool is useful for analyzing processes that use hazardous materials, whether or not they are covered by any specific regulation. The QPRS Tool can be very useful when combined with Process Hazard Analysis (PHA) because it provides a more quantitative means of further defining hazards. The analysis provided under the QPRS Tool provides management with semi-quantitative information in making sound business decisions regarding risk management.

Eight Steps

The QPRS Tool is an eight-step procedure to review any process using, storing, or handling hazardous materials. Each major segment of a process should be reviewed separately (i.e. unloading operation, storage tank, mixing vessel, drumming or packaging operation, coater head, etc.). A flow chart of the QPRS Tool application is shown in Figure 1. A Microsoft Excel workbook has also been developed to facilitate the calculation process.

The QPRS Tool uses commonly available chemical hazard information that is largely present on or determinable from Material Safety Data Sheets. Here is a summary of the eight steps:

1. Materials used in the process are screened to exempt processes that do not use hazardous materials.

2. Processes are then screened to exempt those with small quantities of low hazard materials and no history of releases or process incidents.
3. Remaining processes are reviewed to establish a Process Hazard Index. This is a numeric rating based on process factors including types of hazards present, quantities of materials used, temperatures, pressures, reactivity, operating experience, etc.[1]
4. The Process Hazard Index value is then adjusted for risk reduction(s) afforded by mitigation systems and other safeguards on the process.[2]
5. The resulting adjusted rating, along with the history of releases from the process, are then evaluated in a Hazard Evaluation Matrix.
6. The Hazard Evaluation Matrix generates an estimate for the magnitude of risk the process presents.
7. Potential for on-site and off-site impacts from a release from the subject process is estimated next using data tables or simple release modeling techniques.
8. The Hazard Classification provides guidance to the user on types of hazard management measures appropriate for the level of risk presented by the process. Materials used to classify the process risk can also be used to identify additional safeguards and/or corrective actions that may be technically and economically feasible as means of reducing risk, and what priority should be applied.

The resulting hazard / risk evaluation and additional corrective actions (if any) must be documented, and will become part of the Process Hazard Analysis and the Process Safety Information file for the process.

Finally, since risk is the product of the severity and the probability of an event, a risk matrix has been established to provide input on the incident history of the process under evaluation. The Hazard Evaluation Matrix (see Figure 2) provides a ranking of the risk presented by the process being evaluated into one of five Hazard Classes. The range of PHI values used for the five rows of the matrix were determined based on benchmarking analysis of actual processes by the development team, to form a consensus of level of hazards these benchmarked processes present.

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[1] The Process Hazard Index (PHI) developed in Step 3 is adapted from a risk screening technique developed by Eli Lilly and Company and presented in a paper at the 1993 CCPS International Process Safety Management Conference and Workshop (see Reference #1). The PHI is a numeric value that represents the "raw" hazard presented by the process, however, it does not allow consideration for engineering and/or administrative controls that may be employed on the process to reduce or manage the hazard.

[2] In Step 4, the benefits afforded by the engineering and administrative controls are factored into the risk assessment process by applying the Loss Control Credit Factors used in the Dow Fire & Explosion Index Hazard Classification Guide (see Reference #2). The application of the Loss Control Credit Factors results in an adjusted Process Hazard Index that more accurately reflects the actual hazard presented by the process.

Quantitative Process Risk Screening Tool Flow Chart

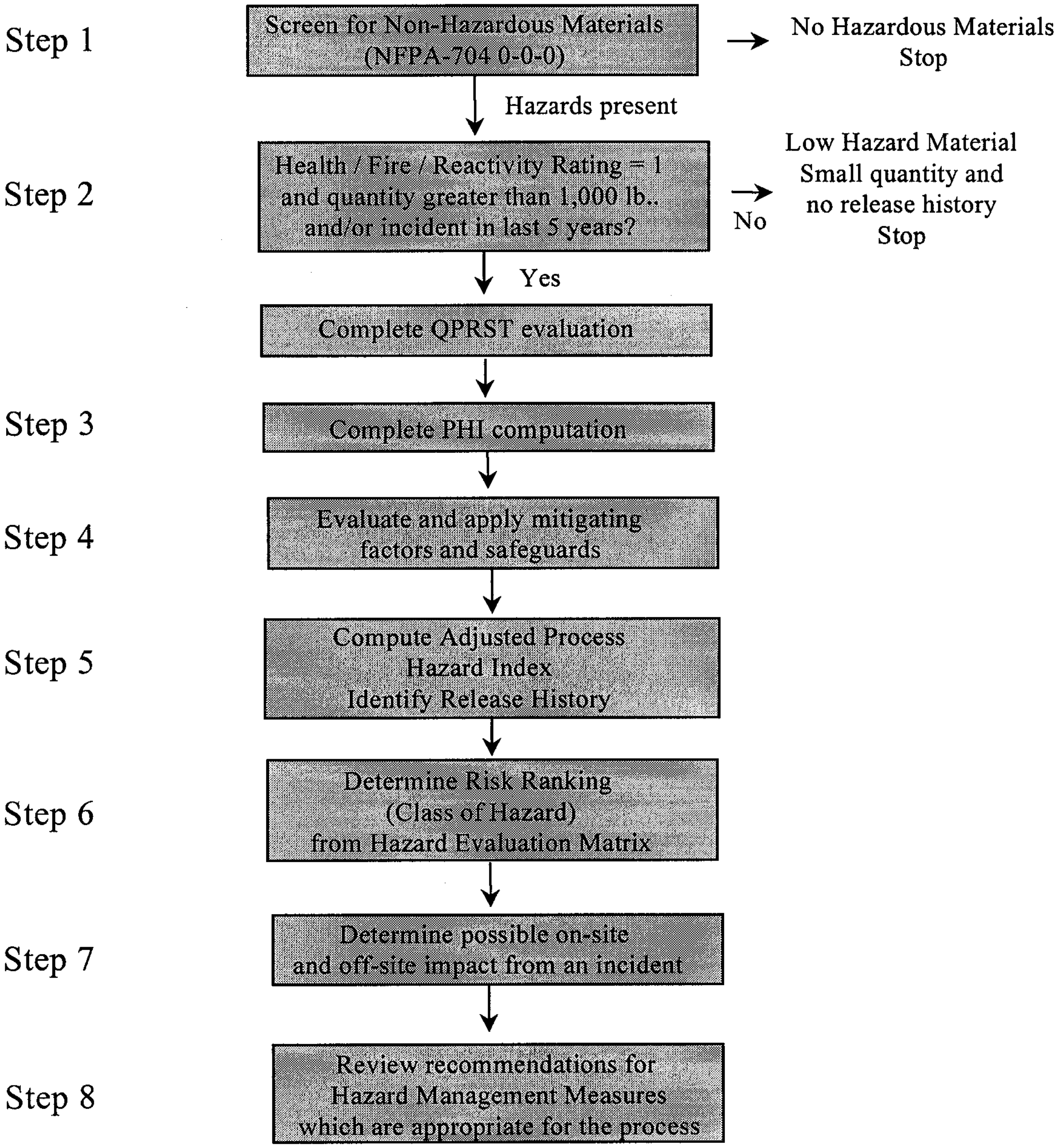

Figure 1

HAZARD EVALUATION MATRIX

Release Frequency History / Hazard Evaluation Index	Improbable (< 1 in 25 years)	Remote (1 in 6 - 25 years)	Occasional (1 in 3 to 5 years)	Probable (1 in 1 - 2 years)	Frequent (> 1 per year)
Process Hazard Index Range < 25	I	I	I	II	III
Process Hazard Index Range 25 - 40	II	II	II	III	IV
Process Hazard Index Range 41 - 100	II	III	III	IV	IV
Process Hazard Index Range 101 - 200	III	IV	IV	V	V
Process Hazard Index Range > 200	IV	V	V	V	V

Figure 2

Hazard Evaluation Matrix Classes—Potential Severity of Risk

The risk matrix allows classification of the risk presented by a specific process to be categorized into one of several possible levels. The Hazard Classes allow for consistent definition of the issues associated with a process and the potential results of an incident involving this process.

The following is a brief description of the potential severity of the on-site / off-site hazards which might be associated with each Class in the Hazard Evaluation Matrix. The estimates are representative for the purposes of describing potential severity associated with a particular class. Actual severity may be much greater or smaller. Each process, whether Class I, II, III, IV, or V must be further analyzed for off-site consequences under Step #7.

Class I Unlikely to adversely affect employees.
Estimated potential damage and production loss less than $25,000.

Class II *Potential for adversely affecting an employee.*
Estimated potential damage and production loss between $25,000 and $50,000.

Class III Potential for adversely affecting several employees.
Estimated potential damage and production loss between $50,000 and $100,000.

Class IV *Potential for adversely affecting many people on-site and some people off-site,*
- and -
Potential for off-site property or environmental damage.

Estimated potential damage and production loss between $100,000 and $1,000,000.

Class V *Potential for adversely affecting many people on-site and off- site,*
- and -
Potential for off-site property or environmental damage.
Estimated potential for damage and production loss greater than $1,000,000.

Consequence Assessment

Supporting documentation provided with the QPRS Tool also allows the user to develop a rough estimate the possible consequences of a fire, explosion or toxic release from the release process. Lookup tables that contain distances to end-points for toxic and fire /explosion are provided for two kinds of generic scenarios involving commonly used hazardous materials as follows:

- Release of a 55 gallon drum quantity in an unconfined area. The scenario is based on the total release of the drum contents over a one minute period. The scenario assumes that after the release, the spill remains unmitigated for a period of 10 minutes (typical of the time to make an emergency notification and implement a response). The model calculates the endpoint distances for fire and toxic exposure, as appropriate, at the end of the 10 minute period. This scenario is also useful for modeling the release of material from a process mixer, coater head or other similar process where a small quantity spill could be anticipated.

- Release of 1,000 gallons of liquid from a storage tank into a diked containment over a 10 minute period. Following the release the spill remains for an additional 10 minute period (again simulating a typical emergency notification and response time). The model then presents both graphic and tabular data for toxic and fire related endpoints based on the square foot area of the diked impoundment. This model is appropriate for bulk storage tanks, tanker unloading, or large process operations where a spill containment dike is provided.

Although these methods result in worst-case release scenarios that are very conservative and do not necessarily take into account some forms of existing mitigation or other factors affecting the probability that such scenarios might occur, the scenarios are based on types of releases that have occurred in industry, and they can, nevertheless, provide additional information on relative hazards associated with particular chemicals.

NOTE: Complete consequence modeling data developed with this tool for use within 3M are not provided as part of this paper. Potential users of the QPRS Tool can develop chemical-specific modeling based on materials and release scenarios that are appropriate for their own facility or company using a variety of release modeling tools such as ARCHIE, ALOHA, or the off-site modeling guidance provided by US EPA for the Risk Management Planning regulations. Examples of the 3M look-up tables are provided in Appendix 1 and 2.

Standard Hazard Management Measures

The Hazard Classification is used to provide guidance on the types of hazard assessments and process safety management practices that may be appropriate for the process under analysis. This approach fosters improved consistency of process hazard management across the entire organization. The following guidance is offered to 3M facilities. These may or may not be appropriate for other industries.

- Processes rated Class I should apply the following methods and techniques for analysis and management of the hazards and risks presented:
  - Written operating procedures.
  - Written maintenance programs and procedures for safety critical equipment.
  - Adherence to applicable company, equipment manufacturer and industry policies, codes and standards for design, operation and maintenance.
  - Application of the OSHA or company Process Safety Management (PSM) standard / policy where quantities of flammable or toxic materials exceed regulatory thresholds or company guidelines.
  - Coordination of emergency response plans with the local fire department for flammables and/or the local LEPC (or equivalent) for toxics.
  - Consideration of additional mitigation measures to reduce risk, balancing the technical and economic feasibility of mitigation measures and the ability of those mitigation measures to reduce or eliminate the risk of adverse effects on and off-site.

- Processes rated Class II should apply the following methods and techniques for analysis and management of the hazards and risks presented:
  - Methods and techniques listed for Class I processes above.
  - Application of company PSM policy if coverage criteria are met as well as application of the OSHA Process Safety Management Standard if chemical threshold criteria for this regulation are met.

- Processes rated Class III should use the following methods and techniques for analysis and management of the hazards and risks presented:
  - Methods and techniques listed for Class II processes above.
  - Assure that assets are in place to support a comprehensive on-site and off-site emergency response plan (i.e. a functioning LEPC, municipal emergency management agency, or equivalent; appropriate response equipment and properly trained personnel; notification systems, etc.) and an effective community relations program for the facility. Facilities should consult with company safety, environmental and public affairs units for assistance in determining specific requirements.

- Processes rated Class IV should use the following methods and techniques for analysis and management of the hazards and risks presented:
  - Methods and techniques listed for Class III processes above.
  - Application of semi-quantitative risk assessment techniques such as Layers of Protection Analysis or others to further quantify risks presented by the process and identify areas where additional process changes or safeguards can be employed.
  - Review of the results of semi-quantitative risk assessment with the appropriate business unit and corporate executives to assure understanding of the risk presented by the process.

- Processes rated Class V should use the following methods and techniques for analysis and management of the hazards and risks presented:
  - Methods and techniques listed for Class IV processes above.
  - Application of a full Quantitative Risk Assessment per guidelines issued by the Center for Chemical Process Safety of the AIChE (or equivalent methodology) to further quantify risks presented by the process and identify areas where additional process changes or safeguards can be employed.
  - Review of the results of the quantitative risk assessment with business unit and corporate management to assure understanding of the level of risk presented by the process.

Alternative Methods for Hazard Management

There may be circumstances in which it is inappropriate to apply the Standard Hazard Management Measures listed above. In such cases 3M facilities are advised to consider Alternative Methods for Hazard Management by following these steps:

- When local laws or regulations prescribe a specific method for Hazard Management that is at least as comprehensive as the "Standard" requirements listed above, the local regulations shall take precedence. When local laws or regulations exist that are less comprehensive than company standard requirements, the facility should implement the requirement prescribed by local law / regulation <u>and</u> shall supplement these actions as necessary to conform to company minimum requirements.

- When other methods of Hazard Management are more appropriate but are not required by local laws or regulations, pre-approval shall be obtained in writing from business unit and corporate management, as appropriate, for the specific Hazard Management practices to be used.

Implementation of Improvements:

A plan should be developed for implementing Action Items. The plan should analyze the Action Items based on the class of hazard, the extent of potential on-site and/or off-site impact, and the level of risk reduction associated with the particular Action Items, among other factors. The plan should provide for expedient implementation of Action Items. If the plan sets any deadlines for implementation of particular Action Items, those deadlines should be realistic. The plan should be communicated to the facility manager and business unit leadership. Periodic reports should be provided to the facility manager and other management personnel as appropriate updating the status and completion of all Action Items.

The following should be documented and be retained with the Process Safety Information:

- The results of the risk evaluation.
- A list of Action Items that are identified to reduce or eliminate identified risks.
- The follow-up actions taken to bring each Action Item to conclusion.

CONCLUSIONS

It has been the experience of one company that a semi-quantitative screening tool can be very effective at maximizing risk management activities and in approaching consistent compliance with General Duty requirements. The use of a simple, standardized approach to hazard assessment and risk management can optimize the allocation of resources required to manage a broad variety of processes and to provide for more consistent application of hazard management techniques across a large, global organization that is impacted by a broad variety of regulatory compliance requirements.

The use of a screening tool allows prioritization of effort and resources to assure that the most serious risks are addressed first. The tool also provides consistent information to management and other decision makers who must make the final allocation of resources across a broad, diverse organization.

APPENDIX 1 – DRUM RELEASE SCENAIO MODELING EXAMPLE

DRUM RELEASE
MODELING SCENARIO SUMMARY

SAMPLE

		Heptane
Liquid Pool Size (sqft)		215
Liquid Evaporation Rate (#/min)		6.5
Liquid Evaporation Duration (min)		10
Toxic Vapor Dispersion Distance (feet)		
	TWA (ppm)	
	TWA Distance*	
	STEL (ppm)	440
	STEL Distance*	58
	IDLH (ppm)	750
	IDLH Distance*	44
Pool Fire Hazard (feet)		
	Burning pool radius/Fireball Diameter	8.3
	Flame height	35
	Fatality zone radius	24
	Injury zone radius	34
Flammable Vapor Cloud Hazard (feet)		
	Downwind hazard distance 100%LFL*	<33
	Downwind hazard distance 50% LFL*	<33
	Max hazard zone width (100% LFL)	<17
	Max hazard zone width (50% LFL)	<17
	Max weight explosive gas (100% LFL)	0.5
	Max weight explosive gas (50% LFL)	0.5
Vapor Cloud Explosion Hazard (feet)#		Improbable#
	1% fatality zone	5
	99% Fatality zone	3
	Probable total buidling destruction	5
	Nearly complete destruction of houses	8
	Wooden utility poles snapped	8
	Frameless steel panel buildings ruined	9
	50% destruction of home brickwork	12
	1% eardrum rupture (exposed pop)	12
	90% eardrum rupture (exposed pop)	5
	Non-reinf. concrete/block walls shattered	14
	Partial collapse of home walls / roofs	14
	Serious / slight injury from flying debris	22
	Partial demolition of homes - uninhabitable	22
	Windows shattered; some frame damage	38
	Some damage to ceilings; 10% wdw brk	59
	Occasional large wdw breakage	415

Models done using ARCHIE software.

*Minimum distance calculated by model is 33 feet.
#Vapor clouds contining less than 1000 pounds of material are unlikely to explode.

Scenario Assumptions: 55 gallon drum (unless otherwise noted) spilled with contents released in one minute period. Pool allowed to evaporate for 10 mintues then is ignited (Based on typical maximum time for
e-squad spill response).

Level of Concern Assumptions: Toxic concentration zone based on Short Term Exposure Limit (STEL) (15 minute exposure limit) unless otherwise noted. Where published, Immediately Dangerous to Life and Health (IDLH) zone also shown.

+ Exposure is based on Ceiling Limit (C-Limit)
++ Calculation based on model minimum concentration of .01 PPM

APPENDIX 2 – BULK MATERIAL RELEASE SCENARIO MODELING EXAMPLE

CHEMICAL RELEASE MODELING SCENARIO SUMMARY						
HEPTANE RELEASE INTO DIKED AREA	**400 Ft² Dike**	**1500 Ft² Dike**	**2000 Ft² Dike**	**3000 Ft² Dike**	**4000 Ft² Dike**	**5000 Ft² Dike**
Liquid Pool Size (sqft)	400	1500	2000	3000	4000	5000
Liquid Evaporation Rate (#/min)	12	45.4	60.6	90.8	121.1	151.3
Liquid Evaporation Duration (min)	2	20	20	20	20	20
Toxic Vapor Dispersion Distance (feet)						
TWA (ppm)						
TWA Distance*						
STEL (ppm)	440	440	440	440	440	440
STEL Distance*	80	160	186	231	268	302
IDLH (ppm)	750	750	750	750	750	750
IDLH Distance*	61	121	141	174	203	228
Pool Fire Hazard (feet)						
Burning pool radius	11.3	21.9	25.3	31	35.7	39.9
Flame height	44	69	76	88	97	105
Fatality zone radius	33	63	72	88	102	114
Injury zone radius	46	89	103	126	146	163
Flammable Vapor Cloud Hazard (feet)						
Downwind hazard distance 100%LFL*	33	<33	36	44	51	57
Downwind hazard distance 50% LFL*	33	44	51	63	73	82
Max hazard zone width (100% LFL)	17	<17	18	22	26	29
Max hazard zone width (50% LFL)	17	22	26	32	37	41
Max weight explosive gas (100% LFL)	0.8	2.9	4.2	7.6	12	17
Max weight explosive gas (50% LFL)	0.8	3.8	5.9	11	17	24
Vapor Cloud Explosion Hazard (feet)#	Improbable#	Improbable#	Improbable#	Improbable#	Improbable#	Improbable#
1% fatality zone	5	8	9	11	12	14
99% Fatality zone	4	6	7	8	9	10
Probable total buidling destruction	6	9	11	13	15	17
Nearly complete destruction of houses	9	14	15	19	22	24
Wooden utility poles snapped	9	14	15	19	22	24
Frameless steel panel buildings ruined	12	19	21	25	29	33
50% destruction of home brickwork	14	21	23	28	33	37
1% eardrum rupture (exposed pop)	14	21	24	19	34	38
90% eardrum rupture (exposed pop)	6	9	10	12	13	15
Non-reinf. concrete/block walls shattered	16	24	27	33	38	43
Partial collapse of home walls / roofs	16	24	27	33	38	43
Serious / slight injury from flying debris	26	40	45	54	63	71
Partial demolition of homes - uninhabitable	26	40	45	54	63	71
Windows shattered; some frame damage	45	68	77	94	109	123
Some damage to ceilings; 10% wdw brk	69	105	119	145	169	190
Occasional large wdw breakage	485	745	842	1026	1195	1342
Models done using ARCHIE software.						

SAMPLE

***Minimum distance calculated by model is 33 feet.**

#Vapor clouds contining less than 1000 pounds of material are unlikely to explode.

Scenario Assumptions: 1000 gallons (unless otherwise noted) spilled with release over 10 minute period. Pool allowed to evaporate for additional 10 mintues then is ignited (Based on typical maximum time for e-squad spill response after discovery).

Level of Concern Assumptions: Toxic concentration zone based on Short Term Exposure Limit (STEL) (15 minute exposure limit) unless otherwise noted. Where published, Immediately Dangerous to Life and Health (IDLH) zone also shown.

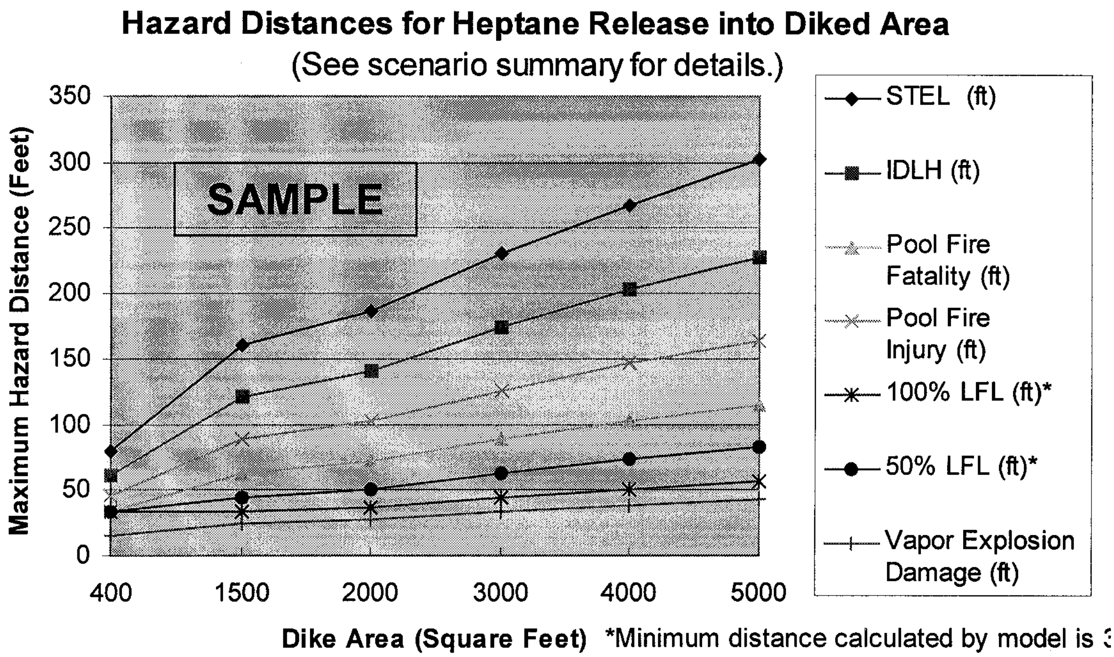

Figure 3

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